exchanger. To mitigate or wholly correct this phenomenon, systems disclosed herein recycle a portion of the product stream once it has been cooled by, for example, a heat exchanger. The recycle stream (i.e., quench stream) of cooled product reduces the temperature of the high temperature product stream to an intermediate temperature which has a reduced rate of undesirable thermal cracking. For example, in some reaction systems disclosed herein, a cooled product stream is recycled to contact the high temperature product stream shortly after the product stream exits the primary separation device that separates most of the solid catalyst from the product stream gas. Examples of solid/gas separation devices suitable for use herein include, without limitation, a cyclonic separation device (i.e., a cyclone), a filter, or any other device suitable for separating gases from solids. Contact by such a quench stream cools the product stream to an intermediate temperature that has a reduced thermal cracking rate as compared to the product stream prior to contact with the quench stream. As such, thermal cracking is reduced at least from the point where the recycle stream (i.e., quench stream) contacts the high temperature product stream to the point where the product stream is cooled by, for example, a heat exchanger.

[0005] According to the present disclosure, a method for forming light olefins may comprise introducing a hydrocarbon feed stream into a reactor, reacting the hydrocarbon feed stream with a dehydrogenation catalyst in the reactor to form a high temperature dehydrogenated product, the dehydrogenated product comprising at least a portion of the hydrocarbon feed stream that was not catalytically reacted, separating at least a portion of the dehydrogenation catalyst from the high temperature dehydrogenated product in a primary separation device, wherein the temperature of the dehydrogenated product and dehydrogenation catalyst in the primary separation device is at least 550°C. The method may further comprise, following the exit of high temperature dehydrogenation product from the primary separation device, combining the high temperature dehydrogenation product with a quench stream to cool the high temperature dehydrogenation product and form an intermediate temperature dehydrogenation product, wherein the quench stream is a gas stream, and wherein temperature of the intermediate temperature dehydrogenation product is at least 10°C less than the temperature of the high temperature dehydrogenation product. The method may further comprise cooling the intermediate temperature dehydrogenation product to form a cooled dehydrogenation product, wherein a portion of the cooled dehydrogenation product is utilized as at least a portion of the quench stream.

[0005a] In an aspect, there is provided a method for forming light olefins, the method comprising: introducing a hydrocarbon feed stream into a reactor; reacting the hydrocarbon feed

stream with a dehydrogenation catalyst in the reactor to form a high temperature dehydrogenated product, the dehydrogenated product comprising at least a portion of the hydrocarbon feed stream that was not catalytically reacted; separating at least a portion of the dehydrogenation catalyst from the high temperature dehydrogenated product in a primary separation device, wherein the temperature of the dehydrogenated product and dehydrogenation catalyst in the primary separation device is at least 550°C; following the exit of high temperature dehydrogenation product from the primary separation device, combining the high temperature dehydrogenation product with a quench stream to cool the high temperature dehydrogenation product and form an intermediate temperature dehydrogenation product, wherein the quench stream is a gas stream, and wherein temperature of the intermediate temperature dehydrogenation product is at least 10°C less than the temperature of the high temperature dehydrogenation product, cooling the intermediate temperature dehydrogenation product to form a cooled dehydrogenation product, wherein a portion of the cooled dehydrogenation product is utilized as at least a portion of the quench stream.

[0006] According to the present disclosure, a method for forming light olefins may comprise introducing a hydrocarbon feed stream into a reactor, reacting the hydrocarbon feed

stream with a dehydrogenation catalyst in the reactor to form a high temperature dehydrogenated product, the dehydrogenated product comprising at least a portion of the hydrocarbon feed stream that was not catalytically reacted, and separating at least a portion of the dehydrogenation catalyst from the high temperature dehydrogenated product in a primary separation device, wherein the temperature of the dehydrogenated product and dehydrogenation catalyst in the primary separation device is at least 550°C. The method may further comprise, following the exit of high temperature dehydrogenation product from the primary separation device, combining the high temperature dehydrogenation product with a quench stream to cool the high temperature dehydrogenation product and form an intermediate temperature dehydrogenation product, wherein the quench stream is a gas stream, and wherein temperature of the intermediate temperature dehydrogenation product is at least 10°C less than the temperature of the high temperature dehydrogenation product. The method may further comprise passing the intermediate temperature product to a secondary separation device, where the remainder of the dehydrogenation catalyst is removed from the intermediate temperature product, and cooling the intermediate temperature dehydrogenation product to form a cooled dehydrogenation product, wherein a portion of the cooled dehydrogenation product is utilized as at least a portion of the quench stream.

[0006a] In another aspect, there is provided a method for forming light olefins, the method comprising: introducing a hydrocarbon feed stream into a reactor; reacting the hydrocarbon feed stream with a dehydrogenation catalyst in the reactor to form a high temperature dehydrogenated product, the dehydrogenated product comprising at least a portion of the hydrocarbon feed stream that was not catalytically reacted; separating at least a portion of the dehydrogenation catalyst from the high temperature dehydrogenated product in a primary separation device, wherein the temperature of the dehydrogenated product and dehydrogenation catalyst in the primary separation device is at least 550°C; following the exit of high temperature dehydrogenation product from the primary separation device, combining the high temperature dehydrogenation product with a quench stream to cool the high temperature dehydrogenation product and form an intermediate temperature dehydrogenation product, wherein the quench stream is a gas stream, and wherein temperature of the intermediate temperature dehydrogenation product is at least 10°C less than the temperature of the high temperature dehydrogenation product; passing the intermediate temperature product to a secondary separation device where the remainder of the dehydrogenation catalyst is removed from the intermediate temperature product; cooling the intermediate temperature dehydrogenation product to form a cooled dehydrogenation product,

wherein a portion of the cooled dehydrogenation product is utilized as at least a portion of the quench stream.

[0007] It is to be understood that both the foregoing brief summary and the following detailed description present embodiments of the technology, and are intended to provide an overview or framework for understanding the nature and character of the technology as it is claimed. The accompanying drawings are included to provide a further understanding of the technology, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments and, together with the description, serve to explain the principles and operations of the technology. Additionally, the drawings and descriptions are meant to be merely illustrative, and are not intended to limit the scope of the claims in any manner.

[0008] Additional features and advantages of the technology disclosed herein will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the technology as described herein, including the detailed description which follows, the claims, as well as the appended drawings.

CLAIMS

1. A method for forming light olefins, the method comprising:

introducing a hydrocarbon feed stream into a reactor;

reacting the hydrocarbon feed stream with a dehydrogenation catalyst in the reactor to form a high temperature dehydrogenated product, the dehydrogenated product comprising at least a portion of the hydrocarbon feed stream that was not catalytically reacted;

separating at least a portion of the dehydrogenation catalyst from the high temperature dehydrogenated product in a primary separation device, wherein the temperature of the dehydrogenated product and dehydrogenation catalyst in the primary separation device is at least 550°C;

following the exit of high temperature dehydrogenation product from the primary separation device, combining the high temperature dehydrogenation product with a quench stream to cool the high temperature dehydrogenation product and form an intermediate temperature dehydrogenation product, wherein the quench stream is a gas stream, and wherein temperature of the intermediate temperature dehydrogenation product is at least 10°C less than the temperature of the high temperature dehydrogenation product,

cooling the intermediate temperature dehydrogenation product to form a cooled dehydrogenation product, wherein a portion of the cooled dehydrogenation product is utilized as at least a portion of the quench stream.

2. The method of any of the preceding claims, wherein the hydrocarbon feed comprises propane, n-butane, iso-butane, ethane, ethylbenzene, or combinations thereof.

3. The method of any of the preceding claims, wherein the quench stream is at least 300°C less than the temperature of the high temperature dehydrogenated product.

4. The method of any of the preceding claims, wherein the rate of thermal cracking in the intermediate temperature dehydrogenation product of the portion of the hydrocarbon feed stream that was not catalytically reacted is less than 90% of that in the high temperature dehydrogenated product.

5. The method of any of the preceding claims, further comprising passing the intermediate temperature product to a secondary separation device where the remainder of the dehydrogenation catalyst is removed from the intermediate temperature product.

6. The method of any of the preceding claims, wherein the cooled dehydrogenation product has a temperature of less than or equal to 150°C.

7. The method of any of the preceding claims, wherein a heat exchanger and/or liquid quenching system cools the intermediate temperature dehydrogenation product to the cooled dehydrogenation product.

8. The method of any of the preceding claims, wherein the quench stream comprises less than 3 wt.% steam.

9. The method of any of the preceding claims, wherein the dehydrogenation catalyst is a solid and the high temperature dehydrogenated product is a gas.

10. The method of any of the preceding claims, wherein the quench stream comprises one or more of ethylene, propylene, or a butene isomer.

11. The method of any of the preceding claims, wherein the dehydrogenation catalyst is a gallium and/or platinum catalyst.

12. A method for forming light olefins, the method comprising:

introducing a hydrocarbon feed stream into a reactor;

reacting the hydrocarbon feed stream with a dehydrogenation catalyst in the reactor to form a high temperature dehydrogenated product, the dehydrogenated product comprising at least a portion of the hydrocarbon feed stream that was not catalytically reacted;

separating at least a portion of the dehydrogenation catalyst from the high temperature dehydrogenated product in a primary separation device, wherein the temperature of the dehydrogenated product and dehydrogenation catalyst in the primary separation device is at least 550°C;

following the exit of high temperature dehydrogenation product from the primary separation device, combining the high temperature dehydrogenation product with a quench stream to cool the high temperature dehydrogenation product and form an intermediate temperature dehydrogenation product, wherein the quench stream is a gas stream, and wherein temperature of the intermediate temperature dehydrogenation product is at least 10°C less than the temperature of the high temperature dehydrogenation product;

passing the intermediate temperature product to a secondary separation device where the remainder of the dehydrogenation catalyst is removed from the intermediate temperature product;

cooling the intermediate temperature dehydrogenation product to form a cooled dehydrogenation product, wherein a portion of the cooled dehydrogenation product is utilized as at least a portion of the quench stream.

13. The method of claim 12, wherein the hydrocarbon feed comprises propane, n-butane, iso-butane, ethane, ethylbenzene, or combinations thereof.

14. The method of claim 12 or 13, wherein the rate of thermal cracking in the intermediate temperature dehydrogenation product of the portion of the hydrocarbon feed stream that was not catalytically reacted is less than 70% of that in the high temperature dehydrogenated product.

15. The method of claim 12, 13, or 14, wherein the cooled dehydrogenation product has a temperature of less than or equal to 150°C.

16. The method of any one of claims 1 to 11, wherein the reactor comprises at least one reactor section operating as a fast fluidized, turbulent, or bubbling bed upflow reactor or a dilute phase riser reactor.

17. The method of any one of claims 12 to 14, wherein the reactor comprises at least one reactor section operating as a fast fluidized, turbulent, or bubbling bed upflow reactor or a dilute phase riser reactor.